The Economic Benefits of Allocating Spectrum for Mobile Broadband in Korea

An Input-output Anlysis

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Abstract— **In South Korea at the year-end 2013, the spectrum regulatory agency finalized the "Mobile Gwanggaeto Plan 2.0" for finding and supplying 1190 MHz bandwidth of spectrum that will be allocated for mobile communication in 4 phases by 2023. So the main purpose of this study is to find an economic impact on mobile broadband spectrum allocation below of 3.6 GHz with economic benefits by means of estimating service revenues and using an input-output analysis. The newly-added benefits will be 159.6 trillion Won and creating more than 182,500 jobs over 7 years.**

Keywords- spectrum; input-ouput analysis; economic benefits.

I. INTRODUCTION

The global market scale of mobile communications has manifested a trend of continuous while the development of the third-generation (3G) network evolving into Long Term Evolution (LTE) has accelerated its pace. The Global mobile Suppliers Association (GSA) report says that 300 LTE networks around the world have been put into commercial service in 107 countries up to June 2014, and forecasts 350+ commercially launched LTE networks by end 2014 [1].

Currently, South Korea's LTE service has grown faster than expected. For instance, LTE penetration rate to exceed 58% by May 2014 [2], and LTE traffic rates on the network is 89% in comparison with mobile communication [3].

South Korea has assigned 390 megahertz (MHz) for Mobile systems so far, as shown in Table I. 330 MHz of the spectrum is utilized to the frequency division duplex (FDD), else 60 MHz to the time division duplex (TDD) as mobile WiMAX.

TABLE I. SPECTRUM ALLOCATION FOR MOBILE IN SOUTH KOREA

Band (MHz)		Uplink		Band width	Downlink		Sum-up
		lower	*upper*		*lower*	*upper*	
2G	800	824	829	5	869	874	10
	1800	1770	1780	10	1860	1870	20
3G	2100	1940	1980	40	2130	2170	80
WiMAX	2300	TDD		60	2300	2360	60
LTE	800	819	824	5	864	869	50
		829	849	20	874	894	
	900	905	915	10	950	960	20
	1800	1715 1730	1725 1735	15/20	1810	1830	70
		1735 1745	1740 1755	15/20	1830	1850	
	2100	1920	1940	20	2110	2130	40
	2600	2520	2540	20	2640	2660	40
Sum-up							390

But according to the Ministry of Science, ICT & Future Planning (MSIP) spectrum regulatory agency in Korea, South Korea wireless networks carried approximately 444 petabytes per month in 2023 [4], a greater than 26-fold increase in comparison with 2011.

The growth of wireless broadband will be constrained if government does not make spectrum available to enable network expansion and technology upgrades. In the absence of sufficient spectrum, network providers must turn to costly alternatives, such as cell splitting, often with diminishing returns. And also the progression to 4G LTE technologies may require appropriately sized bands, including larger blocks to accommodate wider channel sizes.

In order to meet growing demand for wireless broadband services, and to ensure that MSIP finalized "Mobile Gwang-gae-to Plan 2.0" for finding and supplying 1190 MHz bandwidth of spectrum will be allocated for mobile communication like LTE in 4 phases by 2023 [4]. The term "Gwang-gae-to" is the most famous king name for the territorial expansion in Korean history and that means "broadband". 110 MHz bandwidth has already secured, including 40 MHz bandwidth in the 700 MHz band, 30 MHz bandwidth in the 1.8 GHz band and 40 MHz bandwidth in the 2.6 GHz band. Of this total amount of 1190 MHz bandwidth between 700 MHz and around 6 GHz should be made available for mobile use within 10 years. The timeline in Table II illustrates a schedule of actions. This plan had to be modified in consideration of the accelerated increase of mobile traffic due to the evolution of mobile communication technologies, expiration of the use of existing bands and increasing demands for broadband spectrums.

TABLE II. THE MOBILE GWANGGAETO PLAN 2.0 IN KOREA

Category (MHz)		Secure Possible Bandwidth (MHz)					Total
		Secured	*Phase1*	*Phase2*	*Phase3*	*Phase4*	
FDD	700	40					40
	1800	30			20(20)		50(20)
	2100	-	(60)	60			60(60)
	2600	40	20			10	70
TDD	2000			40			40
	2300			30(40)			30(40)
	2500		40				40
FDD/TDD	3500			160			160
WRC	6000				200	500	700
Total	Adding	110	60	290	220	510	1190
	Refarming		(60)	(40)	(20)		(120)

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The main purpose of this study is to find an economic impact on mobile broadband spectrum allocation with economic benefits by means of estimating service revenues and using an input-output analysis.

The rest of this paper is organized as follows. Section II describes the study design issue. Section III goes into finer details results with respect to the contribution of Gross Domestic Product (GDP) and job creation. Section IV addresses the conclusion remarks.

II. STUDY DESIGN ISSUE

A. The past research and literature

Both historical and international experiences have testified that the mobile Internet can contribute to economic growth. Of course, this is not just due to the need of production input to build networks and sell mobile phones, but more importantly, due to the fact that the mobile Internet can advance the spread of information, improve productivity and efficiency, and enable individuals to explore new market and services in the whole economy. Some of the studies highlighted below in this key source suggest that countries can accelerate economic growth and productivity by increasing mobile broadband Internet adoption and usage.

Deloitte has estimated that a 10% rise in 3G penetration increases GDP per capita growth by 0.15 percentage points [5]. Plum report demonstrates that mobile services generate the greatest economic value of eight major applications of spectrum, and estimates the economic value of spectrum used for mobile could reach €477 billion by 2023 [6]. Other report estimates that the reassignment of 300 MHz of spectrum to mobile broadband within five years will spur $75 billion in new capital spending, creating more than 300,000 jobs and $230 billion in additional GDP [7].

A joint research by the GSM Association (GSMA) and the Boston Consulting Group (BCG) has also found that if Asia-Pacific nations were to allocate the 108 MHz spectrum (698 to 806 MHz) to mobile broadband, then in the period from 2014 to 2020, this would contribute 68.4 billion USD to the GDP growth in South Korea [8].

B. Loglet Analysis

Many diffusion models outline the consumption styles of homogeneous consumers in the same population. However, a specific service can be divided into a few heterogeneous groups, showing different diffusion processes. For instance, the mobile service is one communication service with several different generation subscribers – 2G, 3G and 4G. According to related subscribers and service income of mobile communications network, we have chosen the S-shaped analysis and prediction of complex growth processes as the basic formula for our forecast. In this study, the Loglet analysis model will be used, which provides the tool for analyzing the demand diffusion patterns of mobile broadband groups separated from the entire mobile communications, using the business plan of mobile service operators and the series of the demand-data collected so far. Particularly, this study aims primarily to make a mobile broadband-use demand diffusion patterns, which shows the fast growth in demand along with 4G LTE service in Korea.

The Loglet is composed with various logistic curves. The solution to the logistic differential (1) is :

$$P(t) = \frac{\kappa}{1+\exp(-\alpha(t-\beta)} \tag{1}$$

(1) has three parameters; the saturation point of demand **κ**, the growth time reaching a 90% saturation point from the 10% one **α**, and the turning point of the logistic curve **β**. The parameter **α** is usually more useful than △t for the analysis of historical time-series data. The parameter **β** specifies the time when the curve reaches 1/2 **κ**, often re-labeled **tm.**

The formula below illustrates the Loglet as the sum of logistic models. Through simple algebra, the characteristic duration is related to **α** by ln(81) /△**t**. The parameter **β** specifies the midpoint of the growth trajectory as **tm**. The parameter **κ** is the asymptotic limit that the growth curve approaches as like market niche or carrying capacity [9].

The formula below in (2) illustrates the Loglet model for the total mobile broadband subscribers as the sum of logistic models. The three parameters **κ**, △**t**, and **tm** define the parameterization of the logistic model used as the basic building block.

$$N(t) = \frac{\kappa}{1+\exp\left[-\frac{\ln(81)}{\Delta t}(t-t_m)\right]} \tag{2}$$

C. The input-output model

The input-output (I-O) model is the most commonly applied method for economic analysis. Its developer, Wassily Leontief, received the Nobel Prize for Economic Science in 1973 [10]. Within the I-O framework, transactions between industries are modelled to examine the quantitative relationship between the supply of industry inputs and the range of produced outputs.

The I-O model requires that the economy be divided into sectors. Each sector produces goods or services except for the final sector, which only consumes goods and services. A production vector X lists the output of each sector. A final demand vector D lists the values of the goods and services demanded on other productive sectors by the final sector. These intermediate demands are described by the consumption matrix A for the economy.

$$A_{ij} = \frac{Q_{ij}}{Q_i} \tag{3}$$

The equilibrium levels of production for each sector may now be calculated. These equilibrium levels are the production levels which will just meet the intermediate demands of the sectors of the economy plus the final demands of each sector. If X is the desired production vector, X must satisfy

$$X = AX + D \tag{4}$$

In (4), X represents a matrix of gross sector output, A represents a matrix of technical coefficients yielding the input required by one sector to produce a unit increase in a linked sector, and D represents a vector of final demands.

This study used noncompetitive imports and domestic the latest I-O tables for 2009 distributed by Korea's central bank, the Bank of Korea (BOK) to examine the inter-sector effects [11]. So the demand-driven model is used to investigate the production-inducing effect of the mobile broadband service sector on the economy using an exogenous specification. The effect is calculated solving the gross output necessary in each sector for a given set of final demands yields.

$$X = (I - A)^{-1} D \tag{5}$$

In (5), $(I - A)^{-1}$ represents the Leontief inverse matrix or input inverse matrix indicating the total effects on production of a unit increase in final demand with I as the identity matrix. In other words, Column sums of elements in the Leontief inverse describe how an increase in the final demand of a sector impacts on the production levels of all other sectors in the economy and is referred to as the backward linkage effect. Backward linkages provide a measure of each sectors' relative importance as a demander from other upstream suppliers.

Table Ⅲ show the final demand multipliers for the "mobile broadband services" industry that can be used to estimate the impacts of the increase of mobile service revenue on the domestic economy. The total impacts that are calculated using multiplier from this table will include the final-demand change, as well as the direct, indirect effects. This suggests that an increase of $1 in mobile broadband services results in an increase of $1.6864 in final Korea output (or GDP). Using the same hybrid approach, the estimated jobs multiplier for mobile broadband is 7.7007. That is, an increase of $1 million (almost 1 billion Won) in mobile broadband results in roughly 7.7 new Korea jobs.

The increase in mobile broadband revenue may be broken down into the impacts on other industrial sectors in the national level. Therefore, this study is predicting sectoral linkage effects of mobile broadband services, indirect effect is the sum of them by using exogenous specifications for the mobile broadband sector in I-O tables.

TABLE III. FINAL-DEMAND MULTIPLIERS OF MOBILE SERVICES

Industry	Output *(inducement coefficient)*	Jobs *(employ inducement coefficient)*
direct	1.0000	2.8259
indirect	0.6864	4.8748
Sum-up	1.6864	7.7007

III. RESULT OF ANALYSIS

In order to clarify the feasibility and accuracy of this study, the hypothesis involved include a few aspects as follows; Firstly, we classify scenario into the circumstances additional spectrum by increments of 700 MHz below of 3.6 GHz band. Secondly, spectrum amount of 60 MHz mobile WiMAX is excluded in the economic effect, because WiMAX and LTE are strictly divided into different market in Korea government policy. Thirdly, existing use of mobile communication spectrum is 330 MHz. Therefore, analyzing scenario allocate an additional 490 MHz to mobile broadband giving a total of 820 MHz.

On the basis of related parameter estimated by the growth trend in the past years, we have forecasted the mobile broadband subscribers by using the subscribers forecast from the Loglet in Table Ⅳ. And LTE service revenue of mobile communications in the seven-year period from 2014 to 2020 by using the mix of subscribers and year-on-year ARPU in Table Ⅴ. And also we have assumed that the average revenue per user (ARPU) growth will be 3% every step of large supply of frequency by appearance of innovative services in light of annual growth rate of GDP, after then applied to the ARPU decreasing pattern.

The above scenarios, based on the input-output model, the economic impact of spectrum is shown in the following Tables Ⅵ, Ⅶ, Ⅷ. The economic effects of mobile broadband service will be 40 trillion Won, and job creation will be 182.5 thousand man-year in the year 2020. Using an inducement coefficient of 1.6864 and employ inducement coefficient 7.7007.

TABLE IV. MOBILE BROADBAND SERRVICE FORECAST

	2014	2015	2016	2017	2018	2019	2020
Rate (%)	19.2	29.0	41.0	54.0	66.0	75.8	82.9
Subs.(000)	10,985	16,959	24,511	32,856	40,855	47,589	52,715

TABLE V. REVUNUE OF MOBILE BROADBAND SERVICE (TRILLION WON)

	2014	2015	2016	2017	2018	2019	2020
Revenue	4.8	7.6	11.0	14.6	18.4	21.6	23.7

TABLE VI. ECONOMIC EFFECTS OF MOBILE SERVICE (TRILLION WON)

	2014	2015	2016	2017	2018	2019	2020
Direct	4.8	7.6	11.0	14.6	18.4	21.6	23.7
Indirect	3.3	5.2	7.6	10.0	12.6	14.8	16.3
Total	8.1	12.8	18.6	24.6	31.0	36.4	40.0

TABLE VII. EMPLOY EFFECTS OF MOBILE SERVICE (THOUSAND PERSON)

	2014	2015	2016	2017	2018	2019	2020
Direct	13.6	21.5	31.1	41.3	52.0	61.0	67.0
Indirect	23.4	37.0	53.6	71.2	89.7	105.3	115.5
Total	37.0	58.5	84.7	112.5	141.7	166.3	182.5

TABLE VIII. ECONOMIC BENEFITS OF SPECTRUM DEPENDENT SERVICES

Sectors	Y2020 *(Adding 820 MHz)*
Economic effects of mobile service	40.0 *(Trillion Won)*
Job Creation	182.5 *(Thousand man-year)*

IV. Concluding Remarks

Spectrum has a prominent contribution to economic growth, albeit with significant variation from one industry to another. According to our analysis and estimate, with the continuous increase of data traffic, to satisfy the demands of the developing 3G and 4G mobile services, South Korea will experience a shortage of spectrum after 2014. Scarcity of spectrum resources means it needs to be used more efficiently. Because of legacy radio services currently operating on some of the candidate band, often with out of date technology or with an inefficient use of frequency, it is relatively difficult to recycle and adjust some of the candidate band. So, spectrum regulatory agency MSIP finalized “Mobile Gwang-gae-to Plan 2.0” for finding and supplying 1190 MHz of spectrum will be allocated for mobile communication in 4 phases by 2023 at the year-end 2013.

This study aims to find an economic impact on mobile broadband spectrum allocation with economic benefits by means of estimating service revenues and using an input-output analysis. In order to clarify the feasibility and accuracy of this study, the hypothesis involved include a few aspects as follows; Firstly, we classify scenario into the circumstances additional spectrum by increments of 700 MHz below of 3.6 GHz band. Secondly, spectrum amount of 60 MHz mobile WiMAX is excluded in the economic effect, because WiMAX and LTE are strictly divided into different market in Korea government policy. Thirdly, existing use of mobile communication spectrum is 330 MHz. Therefore, analyzing scenario allocate an additional 490 MHz to mobile broadband giving a total of 820 MHz.

Assigning additional spectrum scenario of 820 MHz into the mobile broadband service could yield an additional 40.0 trillion Won for the Korean economy in the year 2020. The newly-added benefits will be 159.6 trillion Won and creating more than 182,500 jobs over 7 years.

This paper is a pioneering study in the assessment of economy-wide effects of the mobile broadband service industries in Korea. The results provide valuable information to policy makers and decision makers by using I-O analysis. Future research needs to be undertaken to compare the marginal utility with increasing spectrum supply. Such a comparison may provide more insightful and practical results.

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